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Presentation by
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Office of Advanced Research and Technology
National Aeronautics and Space Administration

Government Paint Symposium
Annual Meeting of National Paint, Varnish and Lacquer Association
The Statler-Hilton
Dallas, Texas
November 11, 1964

This afternoon I wish to discuss a research program dealing with the development of thermal control coatings for space vehicles. The type of coating that I am about to describe has a limited market as presently used, but your program chairman thought that you would be interested in hearing about our special needs and how they are being met.

I realize that you have dealt with such coatings and their problems since the very beginning of your organization - for after all, have we not been told that we are all passengers on a large space vehicle called Earth which takes 365 days to complete its elliptical orbit around the Sun? Furthermore, many of the paints or coatings which you develop, manufacture -- and sell -- are designed for either reflection or absorption of solar radiation and thus to assist in controlling the temperature of the painted surface, as well as for other purposes.

Why then should the National Aeronautics and Space Administration (NASA) be involved in a program to develop special coatings for space vehicles? The answer is two-fold.

First, the coatings must be designed to quantitatively reflect or absorb specified amounts of solar radiation, and conversely to radiate heat to space at a known rate.

[redacted]

Secondly, a space vehicle such as an artificial satellite, or even the Earth's natural satellite, the Moon, is not surrounded by an atmosphere which shields its surface from destructive space radiations. One of these radiations is the solar ultra-violet most of which is filtered for us by the ozone in the Earth's upper atmosphere. Another is the high energy particle radiation of the Van Allen regions which lose their energy if they come in contact with the Earth's atmosphere.

Finally, there are the corpuscular radiations originating in the Sun and elsewhere in the universe. These too are effectively absorbed or otherwise interact with the Earth's magnetic field.

In addition, our atmosphere shields us from the flying bits of debris in space called meteoroids which, on occasion, are seen burning up as they enter the earth's atmosphere at high velocities.

The external surfaces of space vehicles are subject to these destructive forces, and coatings which are applied to them must withstand these elements just as your more conventional paints must withstand the weather elements present closer to the earth's surface.

Another major dissimilarity with conventional paint development programs was suggested previously. In NASA's space vehicle program, we are interested in paints as thermal control systems rather than as devices for protecting or beautifying surfaces. There are certain exceptions to this, such as coatings for rocket motor nozzles and possibly protective coatings to minimize reactions with certain propellants, but I don't plan to discuss these today.

The coatings I wish to speak about are essentially white paints. They must be good radiators of heat and at the same time absorb little of the solar thermal radiation, and may I add, these characteristics must or should remain stable for long periods of time.

I'll begin by stating how we use such coatings in various ways as an integral part of the thermal design of space vehicles.

First of all, a white paint can be used to adjust the emittance of a shiny metal or to alter the solar absorptance of a black surface. In general, a mosaic of white paint is often used as a thermal control device to control the ratio of solar absorptance to infra-red emittance and thus the equilibrium temperature of the surfaces. In this instance, gray rather than white paints could be used, but it appears that a white paint of known characteristics is easier to formulate.

If we recall that this so-called equilibrium temperature for an insulated body in space is brought about by a balancing of the absorbed incoming solar energy with that emitted to space, we can compute the temperatures of a space vehicle at a given distance from the sun as a function of the ratio of the solar absorptance to infra-red emittance as shown on the first slide.

(SLIDE #1)

[redacted]

From the lower curve, which has a ratio of absorptance to emittance equal to .25, we see that an insulated space vehicle surface whose equilibrium temperature is 40°F near the earth, heats to over 100°F near the planet Venus, and conversely cools to -40°F near the planet Mars.

We may note also, that moving vertically on the slide to higher values of this ratio, the temperature at a given distance from the sun shows marked increases, and furthermore that if it were possible to change this ratio during flight, the temperature could be held constant, regardless of distance from the sun.

Such a device was actually used on the Mariner Venus probe shown on the next slide.

(SLIDE #2)

This slide shows predicted vs. actual temperatures of various components at the time that the probe was near the planet Venus.

The device used for changing the a/e ratio in flight was a panel of movable shutters or louvers which opened at a predetermined temperature, to allow an increased amount of radiation to space by certain warm electronic components. Think of the weight saving that would be possible if this type of device consisted merely of a paint which would automatically change its a/e or color at a given temperature or which would alter its reflectance characteristics with the application of electric or magnetic fields! These are indeed exciting possibilities, and they are being explored as a part of our program.

Other white paints, for use at higher temperatures, and for coating other types of surfaces are being developed for space vehicle radiators, the counterpart of the water cooled automobile radiator. A closed loop system pumps the liquid coolant from the cabin or heated component area of the space vehicle to the radiator where it is cooled and recirculated. Recalling again that only radiative heat exchange takes place between the radiator and its environment, the radiator must again have known a/e characteristics which are stable in that environment.

Finally, a most exotic use for white paints is for maintaining the cold temperature equilibrium of ultra-cold hydrogen or oxygen tanks in space or on the Moon. Such coatings must have a very low solar absorptance and a very high infra-red emittance, and be able to maintain this a/e ratio for long periods.

I would like now to pause for a moment to go back to 1961 when NASA, operating through the Jet Propulsion Laboratory, let a contract with the IIT Research Institute, (then the Armour Research Foundation), to develop a highly reflective white coating which would not darken or otherwise degrade in the space environment.

Many pigments and binders were screened by accelerated exposure to artificial solar ultra-violet radiation, and the pigment selected is characterized in the next slide.

(SLIDE #3)

This slide indicates the reflectance of chemically pure zinc oxide, prepared by the New Jersey Zinc Company, along with the change produced by approximately 1500 hours of exposure to ultra-violet radiation. The binder selected following similar tests was General Electric's LTV silicone. The combination of the two ingredients into a paint has also proven to be stable. Following this, NASA's Marshall Space Flight Center became interested in this coating for the upper hydrogen stage of the Saturn rocket, and for future hardware involving the storage of cryogenic or super-cold fuels.

Further development of this coating, sponsored by Marshall, which included the adoption of a different curing agent, resulted in a very low a/e ratio and fairly long term stability. The paint is presently scheduled for use in the S-4 hydrogen-fueled stage of Saturn rockets numbered 8, 9, and 10.

Early in 1962, another important series of tests of spacecraft paint was beginning, this time in space, riding aboard the first Orbiting Solar Observatory. Results now in, after 16 months in orbit, show that one of the coatings tested, titanium dioxide in epoxy, degraded more rapidly in space than in the ground based ultra-violet test chamber. Our Ames Research Center in California, which designed these tests and plans to launch future tests of the same type, is studying the reasons for this surprising result.

A second titanium dioxide pigmented coating, using a silicone binder, produced widely varying results in various test chambers involved in a round robin program. In this program tests were conducted in many different facilities. Some showed a higher degradation rate than in space, some showed lower.

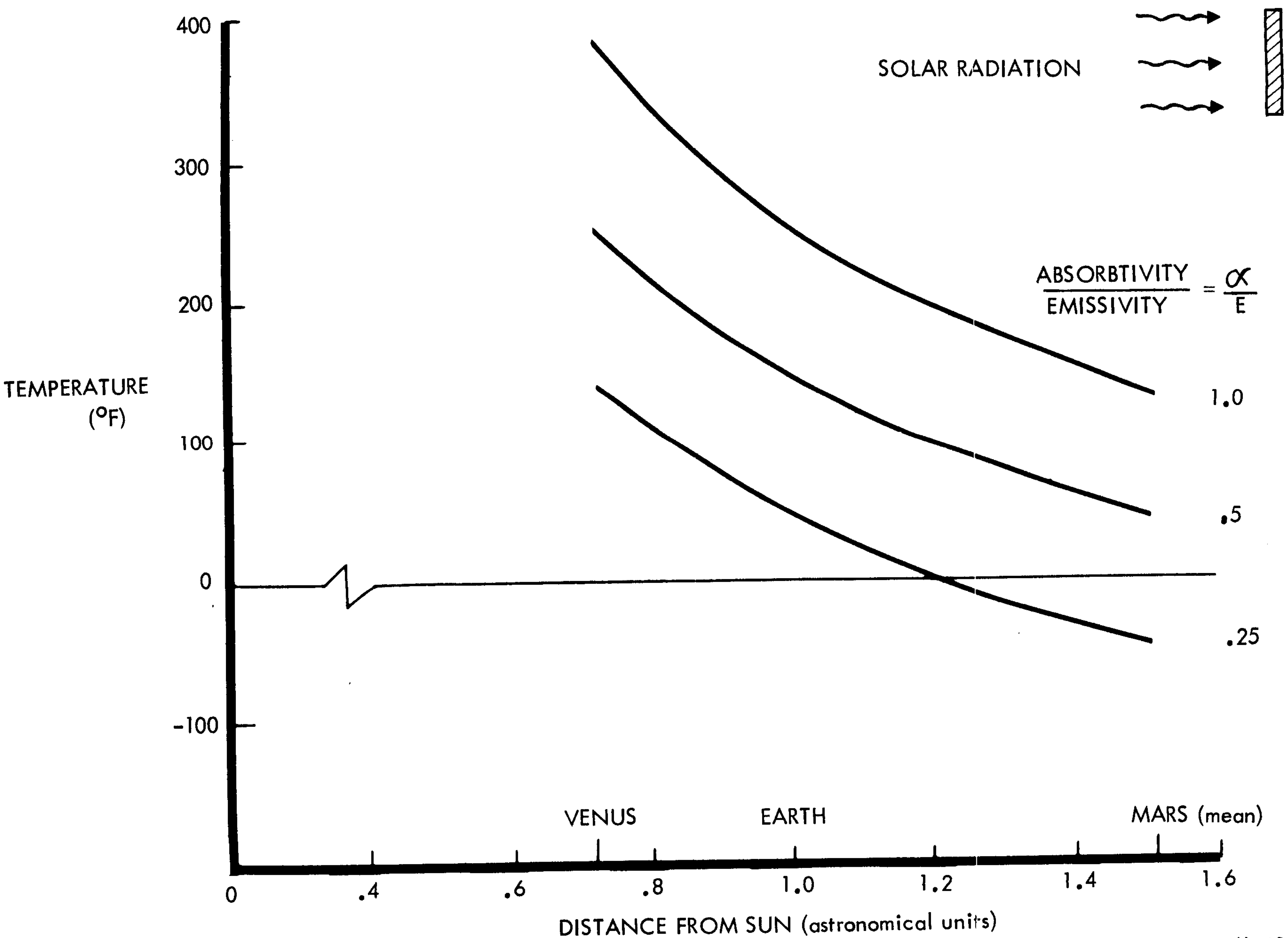
Preliminary results, to be published shortly, show that the degradation rate of the first of the two coatings, unlike the second, was dependent on the temperature of the sample.

Our plans for the future include further development of other thermal control coating materials, some of which may not properly be characterized as paints. We will continue to improve our testing procedures at the ground and in space. We will examine in detail the effects of high energy radiation on coatings both separately and in combination with other environments. We will examine in detail the mechanism of degradation of coatings in space, in the hope that this knowledge will lead to even more stable paint formulations and thus an increased national capability for controlling the temperature of space vehicles.

In this brief discussion of NASA's activities in developing thermal control coatings, we have merely touched upon a very broad effort in this area in which NASA, along with the U.S. military services and other government agencies, has the cooperation of many industrial and educational organizations. We especially welcome this opportunity to discuss our work with your organization and look forward to working together with you again in the future.

Thank you.

TEMPERATURE OF AN INSULATED FLAT PLATE HEATED BY THE SUN



NASA RV-2829-11.63

Fig. 1

MARINER II TEMPERATURES

(AT VENUS)

NASA RV-2801 11.63

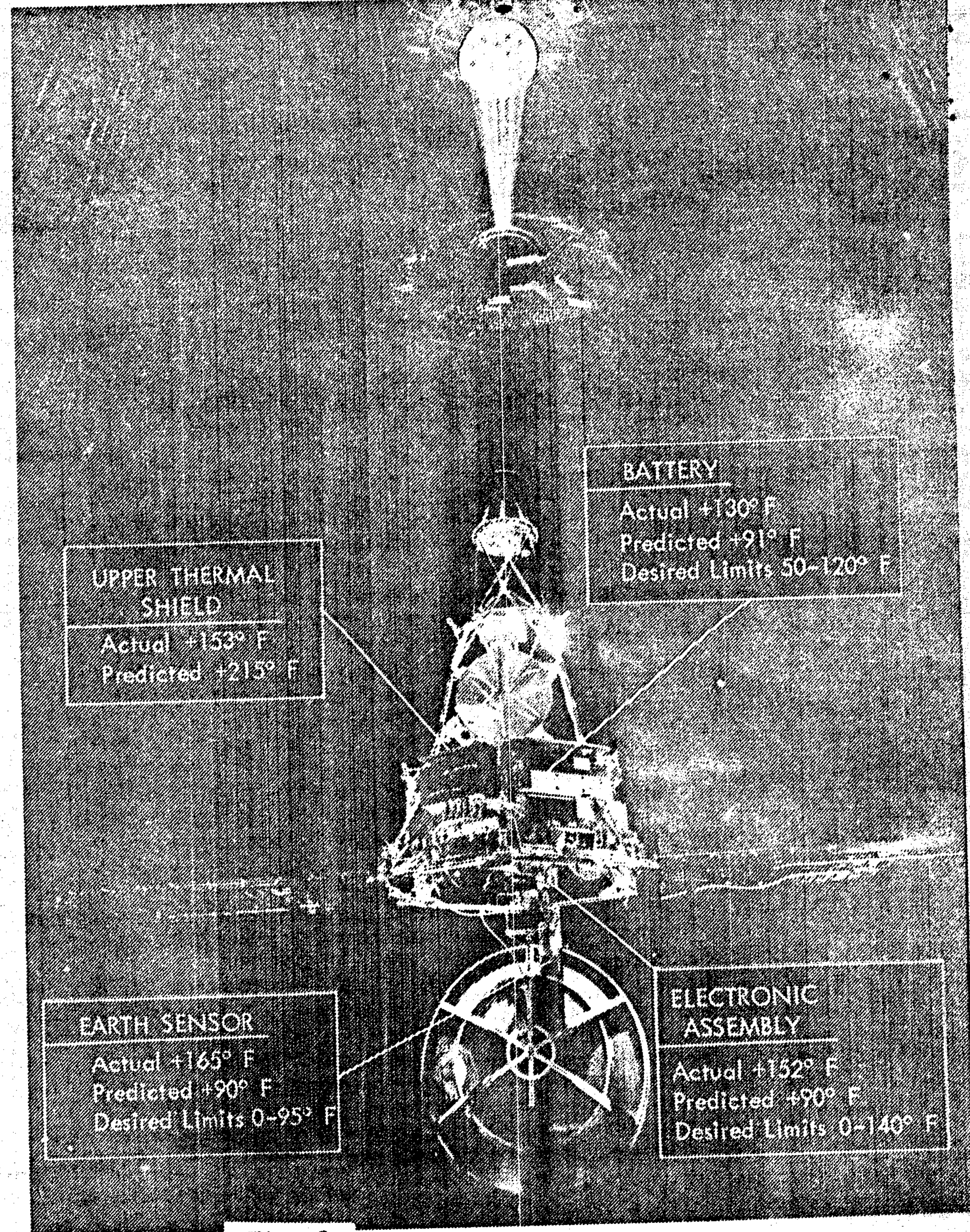


Fig. 2

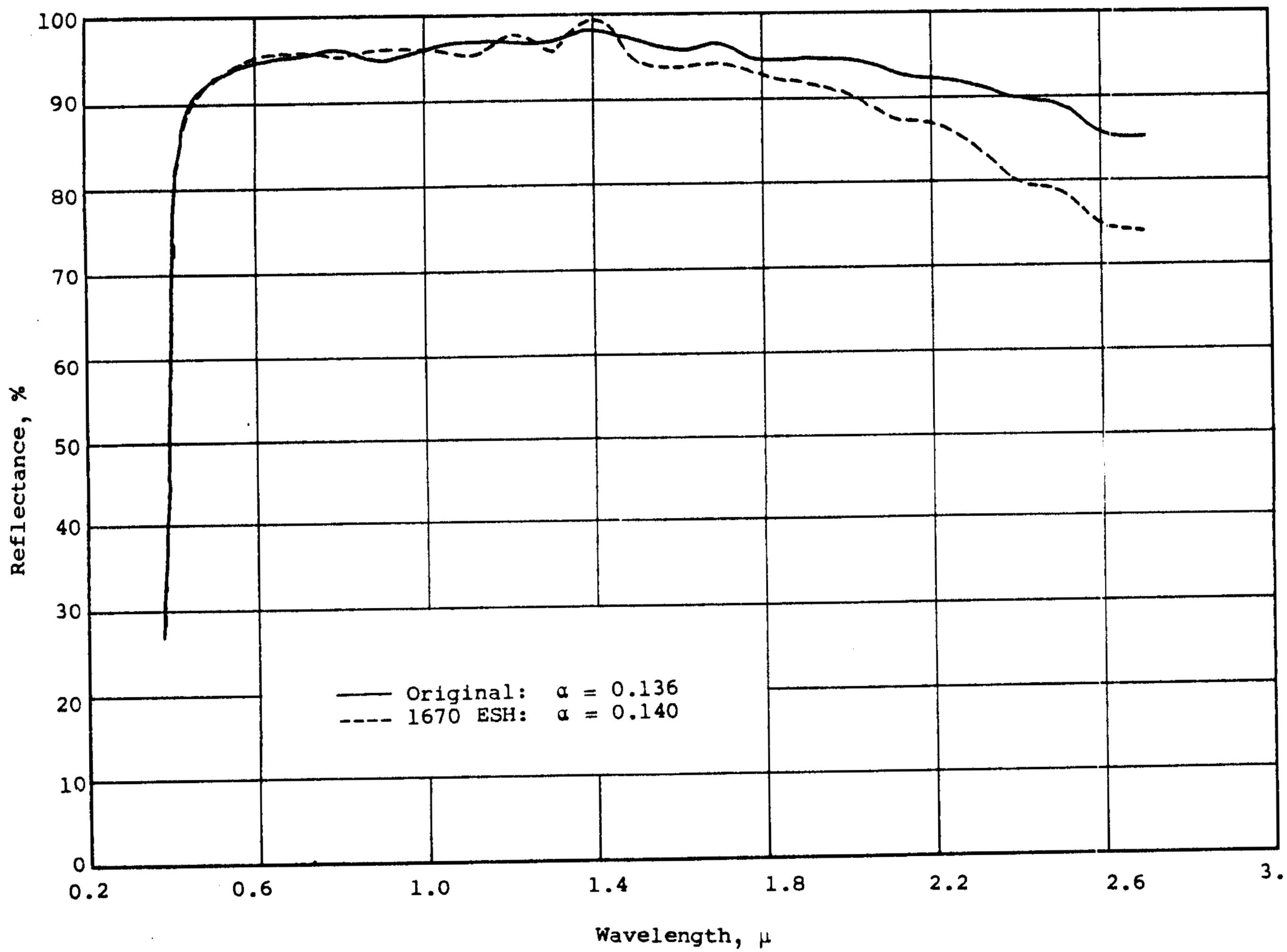


Figure 3
EFFECT OF 1670 HOURS OF EXPOSURE TO SIMULATED SOLAR ULTRAVIOLET ON SP 500 ZINC OXIDE